Practitioner's Docket No. P9153

CHAPTER II

Preliminary Classification:

Proposed Class:

Subclass:

NOTE: "All applicants are requested to include a preliminary classification on newly filed patent applications. The preliminary classification, preferably class and subclass designations, should be identified in the upper right-hand corner of the letter of transmittal accompanying the application papers, for example 'Proposed Class 2, subclass 129.'" M.P.E.P., § 601, 7th ed.

TRANSMITTAL LETTER TO THE UNITED STATES ELECTED OFFICE (EO/US)

(ENTRY INTO U.S. NATIONAL PHASE UNDER CHAPTER II)

PCT/GB98/01155	May 7/98	May 7/97
INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED

GAS DISCHARGE LAMP DRIVE CIRCUITRY
TITLE OF INVENTION

DAVID JOHN AARONS and JOHN MULLENGER
APPLICANT(S)

Box PCT
Assistant Commissioner for Patents
Washington D.C. 20231

ATTENTION: EO/US

CERTIFICATION UNDER 37 C.F.R. § 1.10*
(Express Mail label number is mandatory.)
(Express Mail certification is optional.)

I hereby certify that this Transmittal Letter and the papers indicated as being transmitted therewith is being deposited with the United States Postal Service on this date November 8/99, in an envelope as "Express Mail Post Office to Addressee" Mailing Label Number EJ900522464US, addressed to the: Assistant Commissioner for Patents, Washington, D.C. 20231. ph EJ790052246 4S

Phyllis L. Huggins
(type or print name of person mailing paper)

P L Huggins
Signature of person mailing paper

WARNING: *Certificate of mailing (first class) or facsimile transmission procedures of 37 C.F.R. § 1.8 cannot be used to obtain a date of mailing or transmission for this correspondence.*

"WARNING: *Each paper or fee filed by "Express Mail" **must** have the number of the "Express Mail" mailing label placed thereon prior to mailing. 37 C.F.R. § 1.10(b).*
*"Since the filing of correspondence under § 1.10 without the Express Mail mailing label thereon is an oversight that can be avoided by the exercise of reasonable care, requests for waiver of this requirement will **not** be granted on petition." Notice of Oct. 24, 1996, 60 Fed. Reg. 56,439, at 56,442.*

09/423484

NOTE: To avoid abandonment of the application, the applicant shall furnish to the USPTO, not later than 30 months from the priority date: (1) a copy of the international application, unless it has been previously communicated by the International Bureau or unless it was originally filed in the USPTO; and (2) the basic national fee (see 37 C.F.R. § 1.492(a)). The 30-month time limit may not be extended. 37 C.F.R. § 1.495.

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WARNING: Where the items are those which can be submitted to complete the entry of the international application into the national phase are subsequent to 30 months from the priority date the application is still considered to be in the international state and if mailing procedures are utilized to obtain a date the express mail procedure of 37 C.F.R. § 1.10 must be used (since international application papers are not covered by an ordinary certificate of mailing—See 37 C.F.R. § 1.8.

NOTE: Documents and fees must be clearly identified as a submission to enter the national state under 35 U.S.C. § 371 otherwise the submission will be considered as being made under 35 U.S.C. § 111. 37 C.F.R. § 1.494(f).

I. Applicant herewith submits to the United States Elected Office (EO/US) the following items under 35 U.S.C. § 371:

a. ☒ This express request to immediately begin national examination procedures (35 U.S.C. § 371(f)).

b. ☒ The U.S. National Fee (35 U.S.C. § 371(c)(1)) and other fees (37 C.F.R. § 1.492) as indicated below:

2. Fees

CLAIMS FEE	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
☒*	TOTAL CLAIMS	13 -20=	-0-	× $18.00=	$ -0-
	INDEPENDENT CLAIMS	1 -3=	-0-	× $78.00=	-0-
	MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $260.00	-0-
BASIC FEE**	☐ U.S. PTO WAS INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where an international preliminary examination fee as set forth in § 1.482 has been paid on the international application to the U.S. PTO: ☐ and the international preliminary examination report states that the criteria of novelty, inventive step (non-obviousness) and industrial activity, as defined in PCT Article 33(1) to (4) have been satisfied for all the claims presented in the application entering the national stage (37 C.F.R. § 1.492(a)(4)) ..... $96.00 ☐ and the above requirements are not met (37 C.F.R. § 1.492(a)(1)) ..... $670.00 ☒ U.S. PTO WAS NOT INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where no international preliminary examination fee as set forth in § 1.482 has been paid to the U.S. PTO, and payment of an international search fee as set forth in § 1.445(a)(2) to the U.S. PTO: ☐ has been paid (37 C.F.R. § 1.492(a)(2)) ..... $760.00 ☒ has not been paid (37 C.F.R. § 1.492(a)(3)) ..... $970.00 ☐ where a search report on the international application has been prepared by the European Patent Office or the Japanese Patent Office (37 C.F.R. § 1.492(a)(5)) $840.00				
	Total of above Calculations				= $970
SMALL ENTITY	Reduction by 1/2 for filing by small entity, if applicable. Affidavit must be filed also. (note 37 C.F.R. § 1.9, 1.27, 1.28)				-
	Subtotal				$ 970
	Total National Fee				$ $970
	Fee for recording the enclosed assignment document $40.00 (37 C.F.R. § 1.21(h)). (See Item 13 below). See attached "ASSIGNMENT COVER SHEET".				
TOTAL	Total Fees enclosed				$ 970

*See attached Preliminary Amendment Reducing the Number of Claims. 09/423484

i. ☒ A check in the amount of $970 to cover the above fees is enclosed.

ii. ☐ Please charge Account No. _____ in the amount of $ _____. A duplicate copy of this sheet is enclosed.

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**WARNING: *"To avoid abandonment of the application the applicant shall furnish to the United States Patent and Trademark Office not later than the expiration of 30 months from the priority date: * * * (2) the basic national fee (see § 1.492(a)). The 30-month time limit may not be extended." 37 C.F.R. § 1.495(b).*

WARNING: *If the translation of the international application and/or the oath or declaration have not been submitted by the applicant within thirty (30) months from the priority date, such requirements may be met within a time period set by the Office. 37 C.F.R. § 1.495(b)(2). The payment of the surcharge set forth in § 1.492(e) is required as a condition for accepting the oath or declaration later than thirty (30) months after the priority date. The payment of the processing fee set forth in § 1.492(f) is required for acceptance of an English translation later than thirty (30) months after the priority date. Failure to comply with these requirements will result in abandonment of the application. The provisions of § 1.136 apply to the period which is set. Notice of Jan. 3, 1993, 1147 O.G. 29 to 40.*

3. ☒ A copy of the International application as filed (35 U.S.C. § 371(c)(2)):

NOTE: *Section 1.495 (b) was amended to require that the basic national fee and a copy of the international application must be filed with the Office by 30 months from the priority date to avoid abandonment. "The International Bureau normally provides the copy of the international application to the Office in accordance with PCT Article 20. At the same time, the International Bureau notifies applicant of the communication to the Office. In accordance with PCT Rule 47.1, that notice shall be accepted by all designated offices as conclusive evidence that the communication has duly taken place. Thus, if the applicant desires to enter the national stage, the applicant normally need only check to be sure the notice from the International Bureau has been received and then pay the basic national fee by 30 months from the priority date." Notice of Jan. 7, 1993, 1147 O.G. 29 to 40, at 35-36. See item 14c below.*

a. ☒ is transmitted herewith.

b. ☐ is not required, as the application was filed with the United States Receiving Office.

c. ☐ has been transmitted

i. ☐ by the International Bureau.
Date of mailing of the application (from form PCT/1B/308): _____.

ii. ☐ by applicant on _____.
Date

4. ☒ A translation of the International application into the English language (35 U.S.C. § 371(c)(2)):

a. ☐ is transmitted herewith.

b. ☒ is not required as the application was filed in English.

c. ☐ was previously transmitted by applicant on _____.
Date

d. ☐ will follow.

5. ☐ Amendments to the claims of the International application under PCT Article 19 (35 U.S.C. § 371(c)(3)):

NOTE: The Notice of January 7, 1993 points out that 37 C.F.R. § 1.495(a) was amended to clarify the existing and continuing practice that PCT Article 19 amendments must be submitted by 30 months from the priority date and this deadline may not be extended. The Notice further advises that: "The failure to do so will not result in loss of the subject matter of the PCT Article 19 amendments. Applicant may submit that subject matter in a preliminary amendment filed under section 1.121. In many cases, filing an amendment under section 1.121 is preferable since grammatical or idiomatic errors may be corrected." 1147 O.G. 29-40, at 36.

a. ☐ are transmitted herewith.

b. ☐ have been transmitted

i. ☐ by the International Bureau.
Date of mailing of the amendment (from form PCT/1B/308): _____.

ii. ☐ by applicant on (date) _____.
Date

c. ☐ have not been transmitted as

i. ☐ applicant chose not to make amendments under PCT Article 19.
Date of mailing of Search Report (from form PCT/ISA/210.): _____.

ii. ☐ the time limit for the submission of amendments has not yet expired. The amendments or a statement that amendments have not been made will be transmitted before the expiration of the time limit under PCT Rule 46.1.

6. ☐ A translation of the amendments to the claims under PCT Article 19 (38 U.S.C. § 371(c)(3)):

a. ☐ is transmitted herewith.

b. ☐ is not required as the amendments were made in the English language.

c. ☐ has not been transmitted for reasons indicated at point 5(c) above.

7. ☐ A copy of the international examination report (PCT/IPEA/409)

☐ is transmitted herewith.

☐ is not required as the application was filed with the United States Receiving Office.

8. ☐ Annex(es) to the international preliminary examination report

a. ☐ is/are transmitted herewith.

b. ☐ is/are not required as the application was filed with the United States Receiving Office.

9. ☐ A translation of the annexes to the international preliminary examination report

a. ☐ is transmitted herewith.

b. ☐ is not required as the annexes are in the English language.

10. ☒ An oath or declaration of the inventor (35 U.S.C. § 371(c)(4)) complying with 35 U.S.C. § 115

a. ☐ was previously submitted by applicant on _____. Date

b. ☒ is submitted herewith, and such oath or declaration

i. ☒ is attached to the application. (unexecuted)

ii. ☐ identifies the application and any amendments under PCT Article 19 that were transmitted as stated in points 3(b) or 3(c) and 5(b); and states that they were reviewed by the inventor as required by 37 C.F.R. § 1.70.

iii. ☒ will follow. (executed)

II. Other document(s) or information included:

11. ☐ An International Search Report (PCT/ISA/210) or Declaration under PCT Article 17(2)(a):

a. ☐ is transmitted herewith.

b. ☐ has been transmitted by the International Bureau. Date of mailing (from form PCT/IB/308): _____.

c. ☐ is not required, as the application was searched by the United States International Searching Authority.

d. ☐ will be transmitted promptly upon request.

e. ☐ has been submitted by applicant on _____. Date

12. ☐ An Information Disclosure Statement under 37 C.F.R. §§ 1.97 and 1.98:

a. ☐ is transmitted herewith.

Also transmitted herewith is/are:

☐ Form PTO-1449 (PTO/SB/08A and 08B).

☐ Copies of citations listed.

b. ☐ will be transmitted within THREE MONTHS of the date of submission of requirements under 35 U.S.C. § 371(c).

c. ☐ was previously submitted by applicant on _____. Date

13. ☐ An assignment document is transmitted herewith for recording.

A separate ☐ "COVER SHEET FOR ASSIGNMENT (DOCUMENT) ACCOMPANYING NEW PATENT APPLICATION" or ☐ FORM PTO 1595 is also attached.

_____

_____

_____

14. ☒ Additional documents:
    a. ☐ Copy of request (PCT/RO/101)
    b. ☐ International Publication No. _____
        i. ☐ Specification, claims and drawing
        ii. ☐ Front page only
    c. ☒ Preliminary amendment (37 C.F.R. § 1.121)
    d. ☐ Other

15. ☒ The above checked items are being transmitted
    a. ☒ before 30 months from any claimed priority date.
    b. ☐ after 30 months.

16. ☐ Certain requirements under 35 U.S.C. § 371 were previously submitted by the applicant on _____, namely:

AUTHORIZATION TO CHARGE ADDITIONAL FEES

WARNING: *Accurately count claims, especially multiple dependant claims, to avoid unexpected high charges if extra claims are authorized.*

NOTE: "A written request may be submitted in an application that is an authorization to treat any concurrent or future reply, requiring a petition for an extension of time under this paragraph for its timely submission, as incorporating a petition for extension of time for the appropriate length of time. An authorization to charge all required fees, fees under § 1.17, or all required extension of time fees will be treated as a constructive petition for an extension of time in any concurrent or future reply requiring a petition for an extension of time under this paragraph for its timely submission. Submission of the fee set forth in § 1.17(a) will also be treated as a constructive petition for an extension of time in any concurrent reply requiring a petition for an extension of time under this paragraph for its timely submission." 37 C.F.R. § 1.136(a)(3).

NOTE: "Amounts of twenty-five dollars or less will not be returned unless specifically requested within a reasonable time, nor will the payer be notified of such amounts; amounts over twenty-five dollars may be returned by check or, if requested, by credit to a deposit account." 37 C.F.R. § 1.26(a).

☒ The Commissioner is hereby authorized to charge the following additional fees that may be required by this paper and during the entire pendency of this application to Account No. 08-1254

☒ 37 C.F.R. § 1.492(a)(1), (2), (3), and (4) (filing fees)

WARNING: *Because failure to pay the national fee within 30 months without extension (37 C.F.R. § 1.495(b)(2)) results in abandonment of the application, it would be best to always check the above box.*

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☒ 37 C.F.R. § 1.492(b), (c) and (d) (presentation of extra claims)

NOTE: Because additional fees for excess or multiple dependent claims not paid on filing or on later presentation must only be paid or these claims cancelled by amendment prior to the expiration of the time period set for response by the PTO in any notice of fee deficiency (37 C.F.R. § 1.492(d)), it might be best not to authorize the PTO to charge additional claim fees, except possible when dealing with amendments after final action.

☒ 37 C.F.R. § 1.17 (application processing fees)

☒ 37 C.F.R. § 1.17(a)(1)–(5) (extension fees pursuant to § 1.136(a).

☐ 37 C.F.R. § 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 C.F.R. § 1.311(b))

NOTE: Where an authorization to charge the issue fee to a deposit account has been filed before the mailing of a Notice of Allowance, the issue fee will be automatically charged to the deposit account at the time of mailing the notice of allowance. 37 C.F.R. § 1.311(b).

NOTE: 37 C.F.R. § 1.28(b) requires "Notification of any change in loss of entitlement to small entity status must be filed in the application . . . prior to paying, or at the time of paying . . . issue fee." From the wording of 37 C.F.R. § 1.28(b): (a) notification of change of status must be made even if the fee is paid as "other than a small entity" and (b) no notification is required if the change is to another small entity.

☒ 37 C.F.R. § 1.492(e) and (f) (surcharge fees for filing the declaration and/or filing an English translation of an International Application later than 30 months after the priority date).

SIGNATURE OF PRACTITIONER

Reg. No.: 32,991

Tel. No.: (360) 647-1976

Customer No.:

Todd N. Hathaway
(type or print name of practitioner)

119 N. Commercial Street, Suite 620
P.O. Address
Bellingham, Washington 98225-4437

Practitioner's Docket No. P9153 **PATENT**

☑ Applicant Aarons et al. ☐ Patentee

☑ Application No. 09/423,484 ☐ Patent No.

☑ Filed on 11/08/99 ☐ Issued on

Title: GAS DISCHARGE LAMP DRIVE CIRCUITRY

VERIFIED STATEMENT CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) and 1.27(b))—INDEPENDENT INVENTOR

As a below named inventor, I hereby declare that I qualify as an independent inventor, as defined in 37 CFR 1.9(c), for purposes of paying reduced fees to the United States Patent and Trademark Office under Sections 41(a) and (b) of Title 35, United States Code, to the Patent and Trademark Office, with regard to the invention described in

☐ the specification filed herewith, with title as listed above.

☐ the application identified above.

☑ the patent identified above.

I have not assigned, granted, conveyed or licensed, and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who would not qualify as an independent inventor under 37 CFR 1.9(c), if that person had made the invention, or to any concern that would not qualify as a small business concern under 37 CFR 1.9(d), or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

☐ No such person, concern, or organization exists.

☐ Each such person, concern or organization is listed below.*

*NOTE: *Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)*

FULL NAME _____

ADDRESS _____

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

FULL NAME _____

ADDRESS _____

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

FULL NAME _____

ADDRESS _____

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

DAVID JOHN AARONS
Name of Inventor

Signature of Inventor

Date 05-03-00

JOHN MULLENGER
Name of Inventor

Signature of Inventor

Date

Name of Inventor

Signature of Inventor

Date

SCANNED, # 12

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Aarons et al.	Docket No. P9153
Serial No: PCT /GB98/01155	
Filed: 07/05/98	
For: GAS DISCHARGE LAMP DRIVE CIRCUITRY	

PRELIMINARY AMENDMENT
UNDER 37 C.F.R. 1.121
UPON ENTRY INTO U.S. NATIONAL PHASE

Commissioner of Patents and Trademarks
U.S. Patent and Trademark Office
Washington, D.C. 20231

Sir:

Please amend the above-identified application prior to calculation of the U.S. National Fee and other fees therefor.

IN THE CLAIMS

Please amend claims 3, 4, 5, 8, 10, 12, and 13 as follows:

3. (amended) An electronic circuit (1,3) as claimed in claim 1 [or claim 2], in which the circuit (1,3) has paired outputs (TP10,TP20;TP11,TP21) each pair of which provides a steady low voltage output which may be applied to heated electrodes of the lamp (4).

4. (amended) An electronic circuit (1,3) as claimed in [any preceding] claim 1, in which the means for combining the first

and second series of pulses (P0, P1) includes an isolating transformer means (T0,T1) to electrically isolate the lamp (4) from the power source.

5. (amended) An electronic circuit (1,3) as claimed in [any preceding] claim 1, in which the means (T0,T1,L3) for combining the first and second series of pulses (P0,P1) comprises a first transformer (T0) and a second transformer (T1), the primaries of each transformer receiving respectively the first and second series of pulses (P0,P1), each of the secondaries having a tap (TP30,TP31) which may be electrically connected to the contacts of the lamp (4) and each having another tap (TP40,TP41) electrically connected to the choke (L3) so that the choke combines the secondaries and the choke (L3) in series between the contacts.

8. An electronic circuit (1,3) for controlling a gas discharge lamp (4) as claimed in [any preceding] claim 1, comprising means (1) for shifting the phase of the first series of pulses relative to the second series of pulses, the (T0,T1,L3) for combining the first and second series of pulses (P0,P1) thereby varying the width of pulses in the pulse train.

10. (amended) An electronic circuit (1,3) for controlling a gas discharge lamp (4) as claimed in claim 8 [or claim 9], comprising light level control means for setting a desired intensity of light output from the lamp (4), the means (1) for shifting the

phase of the first series of pulses (P0) relative to the second series of pulses (P1) responding to the light level control means so that the lamp (4) output may be set at a desired level as the width of the pulses is varied.

12. (amended) An electronic circuit (1,3) as claimed in [any preceding] claim 1, in which the pulse train comprises pulses of both positive and negative polarity.

13. (amended) A light fitting having contacts for a gas discharge lamp (4) and an electronic circuit (1,3) as claimed in [any preceding] claim 1.

REMARKS

In accordance with 37 C.F.R. 1.121, this preliminary amendment is submitted to eliminate multiple-dependencies in the claims of the present application, prior to calculation of the U.S. National Fee (35 USC § 1.492) and other fees for entry into the U.S. National Phase.

If there is any matter which could be expedited by consultation with the Applicants' attorney, such would be welcome. The Applicants' attorney can normally be reached at the telephone number below.

Signed at Bellingham, County of Whatcom, State of Washington this 8th day of November, 1999.

Respectfully submitted,

AARONS ET AL.

By ______________________________

Todd N. Hathaway, Reg. No. 32,991
Attorney at Law
119 N. Commercial Street #620
Bellingham, WA 98225
(360) 647-1976

Gas Discharge Lamp Drive Circuitry

The present invention relates to an apparatus and method for driving a gas discharge lamp, and in particular for dimmably or non-dimmably driving fluorescent lamps or tubes.

Fluorescent lamps or tubes are widely used in the home, office and in industry to provide lighting. Such lamps generally consist of a tubular glass envelope, up to 2.44 m (8 feet) long, filled with an inert gas such as krypton or argon which when electrically excited in a gas discharge irradiates a fluorescent coating, such as a powder comprising a (Tb,Ce,Gd,Mg) borate, a (Eu,Ba,Mg) aluminate and a (Y,Eu) oxide, on the inside of the glass. An example of such a tube, 1.22 m (4 feet) long, is the model 'TL'D 36 Watt sold under the trade names "Super 80 (/840) New Generation" and "Standard (/33)" by Philips Electronic and Associated industries Limited.

All gas discharge lamps, including fluorescent lamps, require a ballast to operate. The ballast provides a high initial voltage to initiate the discharge, then rapidly limits the lamp current to safely sustain the discharge. Ballasts are manufactured for three main classes of fluorescent lamp: preheat, rapid start and instant start.

Preheat operation lamp electrodes are heated prior to initiating the discharge. A starter switch closes, permitting a current to flow through each electrode. The starter switch rapidly cools down, opening the switch, and triggering the supply voltage across the arc tube, initiating the discharge. No auxiliary power is applied across the electrodes during operation.

Rapid start operation lamp electrodes are heated prior to

and during operation. A transformer has two special secondary windings to provide the proper low voltage to heat the electrodes.

Instant start operation lamp electrodes are not heated prior to operation. Ballasts for instant start lamps are designed to provide a relatively high starting voltage, as compared with preheat and rapid start lamps, to initiate the discharge across the unheated electrodes.

Prior art document US 4,464,606 discloses a circuit for dimmably controlling a pair of fluorescent lamps, in which a push-pull transistor pair is pulse width modulated to vary the duty cycle of a pulsed current supply to the primary of a transformer to the lamps.

It is desirable to be able to dim fluorescent tubes in order achieve increased energy efficiency when full lighting is not needed. It is known that such tubes up to 1.83 m (6 feet) long can be dimmed with appropriate control circuitry. For example, the above-mentioned 1.22 m fluorescent tube may be dimmably controlled with high frequency regulating ballast sold by Philips Lighting Limited as model number BPL136R.

With reference to Philips Lighting data sheet PL 3322, such known ballasts suffer from a number of limitations. First, it is only possible to achieve adequate control over the dimmable light output for fluorescent tubes up to 1.83 m (6 feet) in length. Secondly, it is only possible to dim down to about 10% of full light output before the tube flickers out. Thirdly, the lighting efficiency of such dimming ballasts drops steadily as the light output falls, the efficiency being 56% at 25% light output and 27% at 10% output, as a result of increased thermal losses in the tube and ballast circuitry. Thus,

[2a-b]

Art 34

the benefit of decreased electricity consumption is not fully realised at low power levels.

The reason for these limitations in performance appears to stem from the way conventional non-dimmable high frequency (hf) ballasts have been adapted for use as

[3→]

dimmable ballasts. A conventional hf ballast generates a pulsed voltage, typically at either 28 kHz or 35 kHz, modulated on and off at a low frequency (50 Hz or 100 Hz), with an on/off ratio of 50% so that there is no hf signal during each half-cycle. A conventional dimmable hf ballast reduces the on/off ratio so that the hf pulsed voltage becomes progressively less than 50% of the duty cycle. The hf pulses are therefore applied to the fluorescent tube for a lower average duty cycle and as fewer hf pulses are applied to the tube, the tube dims.

In general, a number of limitations have been noted with such dimmable systems. First of all, because conventional fluorescent ballasts include a choke with a substantial inductance, proportionately greater amounts of energy are lost in ohmic heating of the choke as the tube is dimmed. Secondly, as the tube is dimmed, a point is reached where the tube fails to strike properly owing to the increasingly large proportion of time when the hf voltage is not applied to the tube. The tube therefore tends suddenly to flicker off before it has been fully dimmed, owing to the increasingly discontinuous nature of the pulse train applied to the tube. These problems become worse for increased length of fluorescent tube and consequently it is believed that there are no commercially available dimmable or non-dimmable ballasts for 2.44 m tubes, and the dimmable ballasts available for 1.83 m tubes do not work as well as those for 1.22 m tubes. See, for example, the comprehensive online database to be found on the internet at http://light-link.com/ which lists all commercially available fluorescent lamps and ballasts. This database lists no commercially available dimmable or non-dimmable ballasts for fluorescent tubes longer than 1.83 m.

The fact that 2.44 m non-dimmable hf fluorescent tube

ballasts are not commercially available is surprising, since there has been a trend since at least 1981 to use non-dimmable hf ballasts for improved energy efficiency whenever possible. High frequency ballasts are, however, known to suffer from various problems.

One problem results from the relatively greater power and hence current and voltage requirements of 2.44 m fluorescent tubes as compared with shorter tubes. Inefficiencies in the ballast circuitry, including transformers, result in excess heating within the ballast unit, which can be damaging to solid state circuit elements. The space within a typical fluorescent tube fitting is quite limited, and it is believed that the build up of heat owing to the relatively greater power requirements has meant that it has not been possible or economic to manufacture a high frequency ballast for a 2.44 m fluorescent tube with a commercially acceptable failure rate, e.g. of less than 1% in the first year after installation.

Another problem is that the circuitry conventionally used generates what are known as "harmonics" and to transmit these harmonics back into the power supply grid. This is a particular problem in certain industrial situations where, for example, a factory may have many hundreds of 2.44 m tubes on a number of lighting circuits supplied through a local step down transformer. In such a situation, harmonics can lead to overloading of transformers, adding of current to the neutral in three phase electrical distribution systems, current/voltage surges or spikes due to circuit resonances with one or more of the harmonic frequencies, and interference with other electronic equipment.

As a result, standards have been introduced to limit the

amount of harmonic distortion produced by high frequency ballasts.

It is an object of the invention to provide a circuit for a high frequency ballast for a gas discharge lamp that addresses these problems and which may be dimmable, and which may be used with certain types of gas discharge lamp such as high output 2.44 m fluorescent lamps which to date have not benefited from the increased efficiencies possible with high frequency operation.

According to the invention, there is provided an electronic circuit for controlling a gas discharge lamp, comprising generation means for generating a high frequency pulse train that may be applied to the electrodes of the lamp to light the lamp, means by which the generation means may be connected to an electrical power source, a choke to limit the current drawn by the lamp, characterised in that the circuit comprises means for producing a first series of pulses and independent from this a second series of pulses, and means for combining additively the first and second series of pulses to produce the high frequency pulse train.

In a preferred embodiment of the invention, the circuit is for a fluorescent lamp.

The term high frequency is intended to exclude frequencies above those used for mains supply, i.e. above 50 to 60 Hz. The value of the high frequency may depend on a number of factors, in particular the type of lamp and the physical size and power rating of the lamp.

The arrangement is such that the rms power level of the high frequency pulse train is determined by the first and second series of pulses, and in particular because the series of pulses are independent of each other may be set

by the relative phases of the first and second series of pulses.

The use of two independent pulse trains combined additively also makes it possible for the voltages of the first and second series of pulses to be less than that supplied as the combined high frequency pulse train applied to the lamp. For example if the voltages of the two series of pulses are the same, then these can then be made to add together so that the combined pulse train has a voltage double that of the each of the series of pulses. The use of lower voltages improves safety and simplifies the design of the generation means.

The choke serves in use to limit the current drawn by the lamp once the gas discharge is struck, and also to provide a high voltage boost to initiate the discharge when the lamp is first started.

Preferably, the means for combining the first and second series of pulses includes the choke which connects together the first and second series of the pulses.

The means for combining the first and second series of pulses includes an isolating transformer means to electrically isolate the lamp from the power source. The output of the circuit would then be floating. It has been found that this helps to prevent capacitative transfer of high frequency voltage to the glass envelope of the lamp, which can cause a unpleasant sensation when the lamp is touched when it is on.

When the circuit is for controlling the light output of a gas discharge lamp, the circuit additionally comprises means for shifting the phase of the first series of pulses relative to the second series of pulses, the means for

combining the first and second series of pulses thereby varying the width of pulses in the pulse train.

By varying the width of the pulses in the pulse train, it is possible to control the rms power supplied to the lamp.

For example, the circuit may comprise means to detect a variation in a supply voltage from the power source. The means for shifting the phase of the first series of pulses relative to the second series of pulses may then responding to a variation in the supply voltage so that the lamp output may be held steady as the supply voltage varies.

The lamp may then also be controlled dimmably, if the circuit comprises light level control means for setting a desired intensity of light output from the lamp. The means for shifting the phase of the first series of pulses relative to the second series of pulses may then responding to the light level control means so that the lamp output may be set at a desired level as the width of the pulses is varied.

It is also possible that the circuit can control a lamp according to the whether or not there is a need foe the light to be on. For example, the circuit may comprise motion detection means to detect motion of an object, such as a person, in the vicinity of the circuit. The light level control means may then respond to the motion detection means so that the lamp output may be set at a desired level according to the detected motion as the width of the pulses is varied.

Whether the circuit is for dimmably controlling or for steadily driving the lamp, the means for combining the first and second series of pulses preferably comprises a

first transformer and a second transformer, the primaries of each transformer receiving respectively the first and second series of pulses, each of the secondaries having a tap which may be electrically connected to the contacts of the lamp and each having another tap electrically connected to a choke so that the choke combines the secondaries and the choke in series between the contacts. The choke is thereby in series with the pulse train.

The choke serves in use to give a high voltage boost if the lamp starts to flicker off at very low power levels, so ensuring that the circuit may control the lamp power close to zero without the need for complicated feedback and lamp drive control circuitry.

The choke also serves to round off any square edges on the high frequency pulse train as the lamp is striking, and it is believed that this effect is important at helping the lamp to work steadily at low power levels, and also to come on at low power levels without the need for any heater element pre-heating delay.

In a preferred embodiment of the invention, the circuit has paired outputs each pair of which provides a steady low voltage output which may be applied to heated electrodes of the lamp.

Then at least one of the transformers may have a secondary winding with a pair of taps that may be electrically connected to heater elements of the lamp. One of the secondary taps for the heater element may then be electrically connected to one of the secondary taps for the lamp contacts so that the heater elements can then receive high frequency pulses with a power level sufficient to heat the heater elements.

Preferably, this power level should be substantially constant and, in the case of the circuit for dimmably controlling the lamp, unaffected by the phase shifting of the first and second series of pulses with respect to one another.

The modulation means may vary the width of each pulse in the pulse train similarly, that is, so that the ratio of on/off time for each combined high frequency pulse is substantially the same.

It would, however, alternatively be possible to vary the width of each combined high frequency pulse in the pulse train dissimilarly, that is, so that the ratio of on/off time for at least some of the adjacent pulses in the pulse train are not substantially the same, so long as the gaps between pulses do not become so long that the pulse train becomes substantially discontinuous, so causing the tube to flicker off at lower average duty cycles.

The pulse train may comprise pulses of just one polarity, but preferably comprises pulses of both positive and negative polarity.

Circuitry such as that described above is not bulky and may readily be incorporated in a light fitting having contacts for a gas discharge lamp. Alternatively, the circuit may be separate from the light fitting, although it would be necessary to provide appropriate transmission lines, e.g. coaxial cable, and shielding to prevent stray leakage of electromagnetic radiation.

The invention will now be further described by way of example to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a circuit for

dimmably controlling a fluorescent lamp according to the invention, having a micro-controller which controls an inverter circuit connected to the lamp;

Figure 2 is a diagram of a pair of wave forms generated by the inverter circuit of Figure 1;

Figure 3 is a circuit diagram of the micro-controller of Figure 1;

Figure 4 is a circuit diagram of the inverter of Figure 1 connected to the lamp;

Figure 5 is a schematic diagram of the output from the inverter across the fluorescent lamp;

Figures 6A to 6L are photographs of oscilloscope traces showing voltages representative of the current supplied by the inverter to the fluorescent lamp, as measured using a feedback winding on the choke; and

Figures 7A to 7I are photographs of oscilloscope traces showing the voltage supplied by the inverter to the fluorescent lamp, as measured across the lamp.

Referring first to Figures 1 and 2, a micro-controller 1 is connected to mains electrical power and a dimmer switch 2. The micro-controller has standard circuitry for mains rectification and stabilisation (not shown), and supplies an inverter circuit 3 with dc power at 320 V, in addition to low voltage dc supply V_{CC} at 5 V and three independent supplies V_{DD1}, V_{DD2} and V_{DD3} at 15 V. The inverter circuit 3 is of the rapid start type.

There is also a feedback line from the inverter 3 to the micro-controller 1, providing a voltage representative of the current drawn by the fluorescent lamp or tube 4, for compensating for line voltage variations and temperature variations of the tube.

The micro-controller digitally generates a pair of signals P0 and P1 which are fed into the inverter circuit 3 as inverter input signals. These input signals are each an essentially continuous train or series of pulses of 0-5 V dc square waves at about 80 kHz with a 50% duty cycle and, as will be explained in more detail further on, the signals P0 and P1 are in phase when the dimmer switch 2 is set for maximum and become progressively out of phase as the dimmer is turned down to off, at which point the signals are out of phase.

Output signals HO, H1 from the inverter 3 are connected to a fluorescent lamp 4, in this example a standard tube 2.44 m (8 feet) long with a rated nominal power of 125 W. Each end of the tube has two contacts connected to the output signals H0, H1 for driving a heater filament in the lamp (not shown) and for supplying the voltage and current needed to strike and light the lamp.

Figure 3 is a circuit diagram of part of the micro-controller 1 comprising a programmable logic device (PLD) chip U1 manufactured by Advanced Micro Devices Inc. as part number MACH215. Chip U1 comprises a counter fed on line 13 a clock signal by a 40 MHz crystal X1. The dimmer switch 2 produces a standard 0-10 V dc output signal, which is converted to 0-5 V dc control input, before being digitized into eight bits D0-D7 by a microcontroller chip U2 manufactured by Arizona Microchip Inc as part number PIC16C73A. The digitized control input is fed to lines 3-10 of chip U1. Each of these lines is connected to a

4.7 kohm pull-up resistor through resistor pack RP1 to the 5 V dc positive supply V_{cc} to ensure that a high signal has the correct voltage.

Chip U2 is powered on after a delay from a Reset in a conventional manner.

The 40 MHz signal from the crystal X1 is divided by 255 inside the chip U1, and this yields a 156.86 kHz signal which is used by firmware in U1 to toggle an output line 41, labelled "PHASE 1A", of chip U1 at 78.43 kHz.

Line 39, labelled "PHASE 1B" is made the logical inverse of PHASE 1A so that the voltage difference between PHASE 1A and PHASE 1B is the square wave signal described in Figures 1 and 2 as the inverter input signal P1. The absolute phase of this signal therefore does not vary.

Available inside chip U1 is a count at 40 MHz from 0 to 255 over one-half cycle of the signal P1. The 8 bits D0-D7 of the digitized 0-5 V control input signal representing the output of the dimmer switch 2 are then compared by firmware in chip U1 with the 40 MHz count from 0 to 255. The chip U1 output line 43, labelled "PHASE 0A", toggles from low to high, and from high to low, whenever the value of the digitized dimmer signal is equal to the value of the 40 MHz count. PHASE 0A, together with its logical inverse from line 40, labelled as "PHASE 0B", produce the square wave signal described in Figures 1 and 2 as the inverter input signal P0. The absolute phase of the P0 inverter input signal relative to the P1 inverter input signal therefore may be varied from in phase (when the voltage from the dimmer switch is 10 V and the count value is 255) to out of phase (when the voltage from the dimmer switch is 0 V and the count value is 0). The P0 and P1 signals are therefore the origin of a first and a second

pulse train, each of the pulse trains being independent of the other.

Microcontroller U2 has outputs Run/Stop, Enable and Write Strobe passed respectively to control chip U1 lines 11, 24, 25. The Write Strobe ensures that the chip U1 latches in the 8 bit value D0-D7 representative of the dimmer switch setting at a defined point in the software cycle at which this value is compared with the 40 MHz count, so that a changing 8 bit value D0-D7 does not affect the operation of the firmware. The Run/Stop is used to switch off the inverter circuit 3 through firmware in U1.

The Enable line is not used in this embodiment of the invention, but could be used to implement pulse width modulation of the pulse train applied to the fluorescent tube 4. When Enable goes high, both P0 and P1 are made to go in phase, whether or not the count is set to 255. It would therefore be possible to make the Enable line switch between high and low at a frequency below the high frequency pulse train at 78.43 kHz, but above mains frequency, for example high 10% of the time and low 90% of the time, so that the width of each pulse in the combined high frequency pulse train is varied dissimilarly, that is, so that the ratio of on/off time for at least some of the adjacent pulses in the pulse train are not substantially the same.

The inverter circuit 3 is shown in more detail in Figure 4, and comprises a pair of similar inverters receiving respectively the inverter input signals P0 and P1. Each signal is passed through a pair of BC337 npn transistors Q5,Q6 and Q7,Q8 to an opto-coupler chip U3, the chip U3 being available from Hewlett Packard as part number HPCL3150. The chip U3 is supplied with three independent supplies V_{DD1}, V_{DD2} and V_{DD3} each at 15 V and each with its

own ground GND1, GND2 and GND3, in order to convert input signals P0 and P1 to 15 V output signals OP1,OP2 and OP3,OP4, which are then passed to a driver circuit which generates through one or the other of a similar pair of step-up output coupling transformers T0,T1, a square wave output signal matching the 0-5 V input signal P0, P1.

The output signal is generated in the following way. Outputs OP1,OP2 and OP3,OP4 are each used to switch a pair of power MOSFETs Q1,Q2 and Q3,Q4, type IRF840, each pair of MOSFETs being wired in series and spanning rectified power rails HT-, HT+ respectively at 0 and 320 V dc. When OP1 (or OP3) goes high, so OP2 (or OP4) goes low goes, and so when one MOSFET is on, the other is off, and vice versa. The voltage at the point between the MOSFETS is half the rail voltage, being split by a pair of 100 nF capacitors. This arrangement produces an output voltage at ± 160 V with respect to the half rail across the primary winding of each inverter output transformer T0,T1 that follows the input voltage at 0-15 V across the MOSFETs. The ratio of primary to secondary windings is 34:51.

The secondary windings of each of the output transformers T0 and T1 have taps TP10,TP20,TP30,TP40 and TP11,TP21, TP31,TP41 at the same number of turns, but in the opposite order so that the output voltages and currents are in the opposite sense. For each transformer, one pair of taps TP10,TP20 or TP11,TP21 supplying 4 V is connected across the heater elements in the fluorescent tube 4 to provide a sufficiently small heating current at 78.43 kHz which remains steady as the phases of the input and output signals are varied with respect to each other.

Another pair of taps TP30,TP40 and TP31,TP41 from each of the output transformers T0,T1 span most of the turns of

the secondary windings. One tap TP30 or TP31 from each of the pairs of taps is connected, respectively to tap TP20 or TP21, and therefore also to one of the lamp heater contacts, with the other two taps TP40,TP41 being connected together through an inductor or choke L3, so that most of the secondary turns of each of the output transformers T0,T1 together with the inductor L3 are in series. The main outputs from the transformers T0,T1 are therefore combined additively by the connection through the choke L3, and this provides the benefit of increasing the voltage present across the tube 4.

When the circuit is energised, current flows in alternate directions around the loop through the tube 4, transformer T0,T1 main secondaries and the choke L3. Because the choke is placed symmetrically between the secondaries, there is only the need for one choke, which helps to reduce resistive losses.

The operation of the inverter circuit of Figure 4 with the fluorescent lamp 4 may be appreciated with reference also to Figure 5 which shows schematically the voltage difference between the two taps TP30,TP31 (or, equivalently, the voltage difference between the two taps TP40,TP41). A dashed line at 0 V indicates the point at which there is no net voltage difference across these taps. When the signals P0 and P1 are out of phase, there is effectively no net voltage across the tube 4 and inductor L3. When the signals P0 and P1 are in phase, the voltages through the output transformers T0,T1 add, to produce the signal labelled in the drawing as "100% Power Output". The resultant voltages are also shown schematically for 25% and 75% output. The inverter circuit 3 therefore combines the pulse train signals P0 and P1 in such a way as to produce resultant voltages which have a varying pulse width for each positive and negative going

pulse, the width varying from effectively 100% of a half cycle of the resultant pulse train down to 0% of a half cycle.

Figures 6A to 6L show photographs of oscilloscope traces of a voltage representative of the current through the inductor L3. The twelve traces show the changes in current from nearly full power to nearly no power. Figures 7A to 7I show photographs of oscilloscope traces of the voltage present across the fluorescent tube. The nine traces show the changes in voltage from nearly full power to nearly no power. Both sets of traces are labelled with "step numbers" that correspond with the data in Table 1 below:

Table 1:

Figure	Step N°	P (W) Meter	P (W) I•V	Light %	Effic L/P %	Temp (°C)
6A	**219**	**120**	**123.2**	**100.0**	**100.0**	**31**
6B	173	111	112.2	91.8	99.3	31
6C	150	101	101.2	83.7	99.4	29
6D	120	88	90.2	76.8	104.8	30
6E	106	81	81.4	71.4	105.8	29
6F	90	69	70.4	56.9	99.0	28
6G	77	60	61.6	45.2	90.5	27
6H	62	50	50.6	31.9	76.5	24
6I	50	40	39.6	21.5	64.6	22
6J	47	23	24.2	2.2	11.4	19
6K	28	20	19.8	0.5	3.3	17
6L	1	18	19.8	0.3	1.8	15

The "Step N°" value is the value of the digitized dimmer signal which shifts the phase of the signals P0 and P1 in and out of phase, with step number values of 255 and 0 being, respectively in phase and out of phase.

The "P Meter" values were measured with an electrical power meter on the mains supply to the apparatus; this measured value takes account of the power factor, that is any phase shift between current I and voltage V which would tend to reduce the consumed power. The "P I•V" values are calculated from measured values of mains supply

voltage V and current I, with no correction for any phase differences between V and I. It will be noted that the close correspondence between the power levels as measured with the meter and those calculated from current I and voltage V shows that unlike conventional fluorescent drivers, the power factor is effectively unity, that is there is effectively no phase shift between current and voltage. The circuit according to the present invention may therefore be useful even when the circuit is used just to drive a gas discharge lamp at a steady power, (i.e. with no phase shift of the first and second series of pulses) since there will be no cumulative shift in power factor as a large number of lamps and circuits are connected to the mains in close proximity with one another.

The mains voltage levels were steady at 220 V throughout the data run. The temperature values were measured with a probe on the glass envelope of the tube, which was a standard 2.44 m (8 feet) long fluorescent tube, manufactured by Osram and nominally rated 125 W.

The light levels were measured with a lux meter with the data normalised to 100% at the reading closest to nominal rated full power of the tube, i.e. 120 W, at which the "step number" was 219.

The column labelled "Effic" gives the relative efficiency of the lamp 4 and electronic circuitry 1,2,3, that is, a value representing Light/P Meter normalised to 100% at step number 219. It will be noted that the relative efficiency is still about 90% when the light has been dimmed to about 45% of nominal full output. Only when the light output has been dimmed to about 21% at a step value of 50, does the efficiency drop off sharply from about 65% when the step value is decreased to 47.

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Further data taken using the same equipment and tube, but under ambient conditions warmer than those for the data of Table 1, are set out in Table 2 below for the full range of step values between 1 and 255:

Table 2:

Step N°	P (W) Meter	P (W) I•V	Light %	Effic L/P %	Temp (°C)
255	136	134.2	105.8	94.9	38
245	134	132.0	104.6	95.3	38
234	129	127.6	102.3	96.8	38
219	**122**	**118.8**	**100.0**	**100.0**	**38**
173	112	107.8	93.3	101.5	36
150	103	99.0	88.2	104.4	36
120	88	83.6	76.3	105.8	36
106	75	72.6	64.0	104.2	34
90	63	59.4	52.2	101.0	33
77	55	50.6	44.3	98.3	32
62	41	35.2	29.0	86.2	31
50	19	15.4	5.6	35.8	30
47	17	13.2	3.5	25.0	28
29	15	11.0	1.2	9.4	25
1	15	4.4	0.5	3.8	24

The data at step value 219 closest to the nominal 125 W

AMENDED SHEET

rated power of the lamp is highlighted in bold on both tables for ease of comparison. The higher ambient temperatures lead to a higher actual light output, and therefore the step value below which the relative light output and relative efficiency begins to drop sharply, is here step number 62. The light output may, however, still be dimmed to about 29% of nominal full output at this point.

Although not implemented in the example described herein, the feedback line from the inverter 3 to the micro-controller 1, providing a voltage representative of the current drawn by the fluorescent lamp or tube 4, may be used to compensate for temperature variations of the tube.

Referring again to Figures 6A to 6L, these show photographs of oscilloscope waveforms representative of the current through the fluorescent tube. In all cases the horizontal time base was set at 2.5 µs/division, making 25 µs across each photograph, with a vertical scale of 2 V/division. A voltage for the traces was generated by a current probe comprising a single turn of wire around the inductor L3, the current through the inductor L3 being essentially the same as the current through the fluorescent tube 4.

Since the inductor L3, together with the secondary windings of transformers T0,T1 between taps TP30,TP40 and TP31,TP41, is in series with the fluorescent tube 4, the impedance of the inductor L3 works as a current limiter to limit the current supplied from the inverters, and also to shape the rise and fall times of the current through the fluorescent tube. It has been found that the selected impedance of the inductor is important insofar as it shapes the rise and fall time of the current through the

fluorescent tube 4. The two transformers T0,T1 and the inductor L3 use a rectangular module and a ferrite core, grade 3C85, manufactured by Philips Components.

Correct design of inductor L3 helps the fluorescent tube to be dimmed to a lower level than would otherwise be possible. It is also important because if the lamp fails to strike, or flickers out at low power, the voltage across the inverters would increase and an auto-restrike would occur. Because of the high frequency operation, this would happen so quickly, that the eye would not be able to detect this restrike.

From Table 1, it can be seen that the apparatus according to the invention may be used to dim a standard 2.44 m (8 feet) long fluorescent tube to less than 1% of full light output. However, because of inevitable power losses in the electronic circuitry and essentially constant heating of the heater elements in the fluorescent tube, the effective range when power saving is the main concern is down to about 22% of full light output.

Although difficult to quantify, it has also been observed that the steadiness and the colour quality of the light output of fluorescent tubes driven by electronic circuits according to the invention, is superior to that achieved by conventional circuits of the type mentioned above. In particular, the colour quality appears to be more constant and whiter than with conventional apparatus as the power is dimmed towards nearly off.

Another advantage is that the power factor of the circuit as connected to the mains is close to unity, as can be seen from Table 1 by comparison of the columns for "Power" and "Power I•V". The circuit described above also does not

inject any significant harmonics back into the power supply. Conventional ballasts relying on relatively large inductive chokes can induce a significant lag between voltage and current.

The circuit also allows operation at about 80 kHz. Compared with a conventional high frequency ballast operating at about 35 kHz, this permits a significant size reduction in transformer windings, and hence in the overall size of the ballast unit. For example, the circuit above has been packaged with all other necessary components in a casing measuring just 40 mm x 45 mm x 320 mm (height x width x length).

Although the invention has been described specifically with reference to a standard 2.44 m (8 feet) long cylindrical fluorescent tube, those skilled in the art will appreciate that the circuit described above may be adapted for other types of fluorescent tube, for example longer or shorter cylindrical tubes, and also compact fluorescent lamps such as those with shaped or curved tubes and those intended as replacements in incandescent light bulb fittings.

The electronic circuit according to the invention can also be used to drive and dimmably or non-dimmably control other types of lamps such as metal halide (HID) and low and high pressure sodium vapour lamps. Such lamps are often used for outdoor lighting such as street lighting. The electronic circuit according to the invention may be then be used with such lamps to dim these when full light output is not needed, such as the small hours of the morning, this saving significant amounts of electrical power and reducing the problem of light pollution around built up areas.

For example, the circuitry described above has also been used to drive and dimmably control 70 W and 250 W high pressure sodium lamp of the type SON-T and also 250 W high pressure sodium lamps with a phosphorescent coating of the type SON-E. These lamps are noted for their high efficiency and used mainly for lighting of roads, and public buildings and spaces. Other lamps that have been successfully driven and dimmed are low pressure sodium lamps up to 250 W, type SOX manufactured by Osram, and high pressure mercury vapour lamps, up to 70 W.

In the case of so-called cold electrode lamps, i.e. those that do not have an electrode heater element and which have just one electrical contact at each electrode, a circuit similar to that described above may be used, with the modification that the wire leading from the end of the secondary to complete a heater element circuit is omitted.

It would also be possible to fit motion detectors, such as those using passive-infra-red sensors, to such dimmable lamps, to control automatically the degree of dimming, for example depending on whether anyone or any vehicle was moving near the lamp.

The circuit described above may, of course, also be modified to drive a fluorescent lamp non-dimmably, for example by providing a constant control input voltage at 5 V in place of the signals from a dimmer or by omitting the part of the circuitry in Figure 3 to do with shifting the phases of the first and second series of pulses.

Gas discharge lamps driven and dimmably or non-dimmably controlled by electronic circuits according to the invention may therefore be suitable for use in many applications in the home and industry, both indoor and outdoor.

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Claims

1. An electronic circuit (1,3) for controlling a gas discharge lamp (4), comprising generation means for generating a high frequency pulse train that may be applied to the electrodes of the lamp to light the lamp (4), means by which the generation means may be connected to an electrical power source, a choke (L3) to limit the current drawn by the lamp (4), characterised in that the circuit comprises means (3) for producing a first series of pulses (P0) and independent from this a second series of pulses (P1), and means (T0,T1,L3) for combining additively the first and second series of pulses to produce the high frequency pulse train.

2. An electronic circuit (1,3) as claimed in Claim 1, in which the means (T0,T1,L3) for combining the first and second series of pulses includes the choke (L3) which connects together the first and second series of the pulses (P0,P1).

3. An electronic circuit (1,3) as claimed in claim 1 or claim 2, in which the circuit (1,3) has paired outputs (TP10,TP20;TP11,TP21) each pair of which provides a steady low voltage output which may be applied to heated electrodes of the lamp (4).

4. An electronic circuit (1,3) as claimed in any preceding claim, in which the means for combining the first and second series of pulses (P0,P1) includes an isolating transformer means (T0,T1) to electrically isolate the lamp (4) from the power source.

5. An electronic circuit (1,3) as claimed in any preceding claim, in which the means (T0,T1,L3) for combining the first and second series of pulses (P0,P1)

comprises a first transformer (T0) and a second transformer (T1), the primaries of each transformer receiving respectively the first and second series of pulses (P0,P1), each of the secondaries having a tap (TP30,TP31) which may be electrically connected to the contacts of the lamp (4) and each having another tap (TP40,TP41) electrically connected to the choke (L3) so that the choke combines the secondaries and the choke (L3) in series between the contacts.

6. An electronic circuit (1,3) as claimed in claim 5, in which at least one of the transformers (T0,T1) has a secondary with a pair of taps (TP10,TP20;TP11,TP21) that may be electrically connected to heater elements of the lamp (4).

7. An electronic circuit (1,3) as claimed in claim 6, in which one of the secondary taps (TP20,TP21) for the heater element is electrically connected to one of the secondary taps (TP30,TP31) for the lamp contacts.

8. An electronic circuit (1,3) for controlling a gas discharge lamp (4) as claimed in any preceding claim, comprising means (1) for shifting the phase of the first series of pulses relative to the second series of pulses, the means (T0,T1,L3) for combining the first and second series of pulses (P0,P1) thereby varying the width of pulses in the pulse train.

9. An electronic circuit (1,3) as claimed in claim 8, comprising means to detect a variation in a supply voltage from the power source, the means for shifting the phase of the first series of pulses relative to the second series of pulses responding to a variation in the supply voltage so that the lamp (4) output may be held steady as the supply voltage varies.

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10. An electronic circuit (1,3) for controlling a gas discharge lamp (4) as claimed claim 8 or claim 9, comprising light level control means for setting a desired intensity of light output from the lamp (4), the means (1) for shifting the phase of the first series of pulses (P0) relative to the second series of pulses (P1) responding to the light level control means so that the lamp (4) output may be set at a desired level as the width of the pulses is varied.

11. An electronic circuit (1,3) as claimed in claim 10, comprising motion detection means to detect motion of an object in the vicinity of the circuit, the light level control means responding to the motion detection means so that the lamp (4) output may be set at a desired level according to the detected motion as the width of the pulses is varied.

12. An electronic circuit (1,3) as claimed in any preceding claim, in which the pulse train comprises pulses of both positive and negative polarity.

13. A light fitting having contacts for a gas discharge lamp (4) and an electronic circuit (1,3) as claimed in any preceding claim.

Abstract

Gas Discharge Lamp Drive Circuitry

The present invention relates to an apparatus and method for driving a gas discharge lamp, and in particular for dimming fluorescent lamps or tubes. An electronic circuit for controlling a gas discharge lamp (4) comprises generation means for generating a high frequency pulse train that may be applied to the electrodes of the lamp (4) to light the lamp, means by which the generation means may be connected to an electrical power source, a choke (L3) to limit the current drawn by the lamp (4), means (3) for producing a first (P0) series of pulses and independent from this a second (P1) series of pulses, and means (T0,T1,L3) for combining additively the first and second series of pulses to produce the high frequency pulse train.

Figure 4

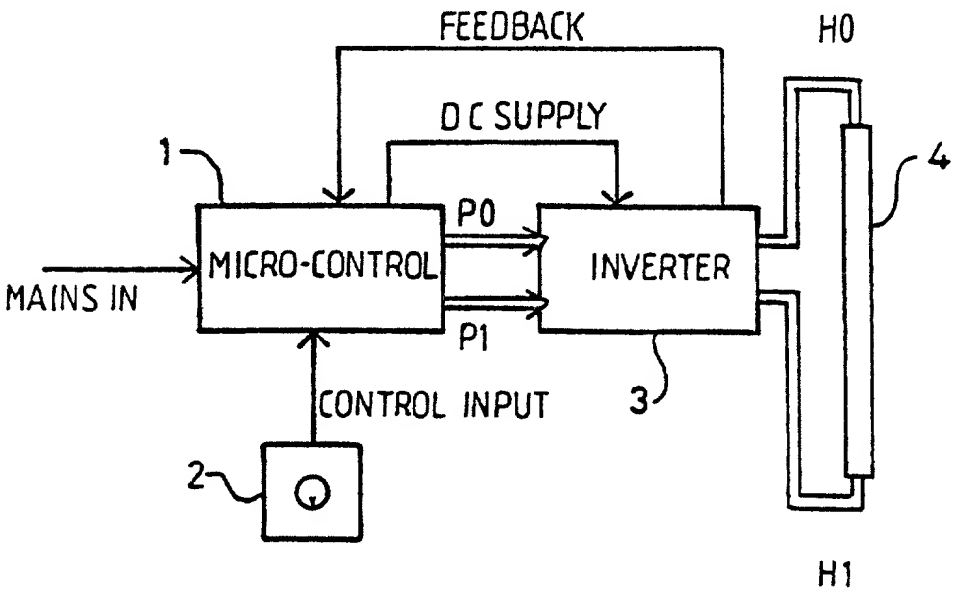
FEEDBACK
HO
DC SUPPLY
1
4
P0
MICRO-CONTROL
INVERTER
MAINS IN
P1
CONTROL INPUT
3
2
H1

Fig. 1

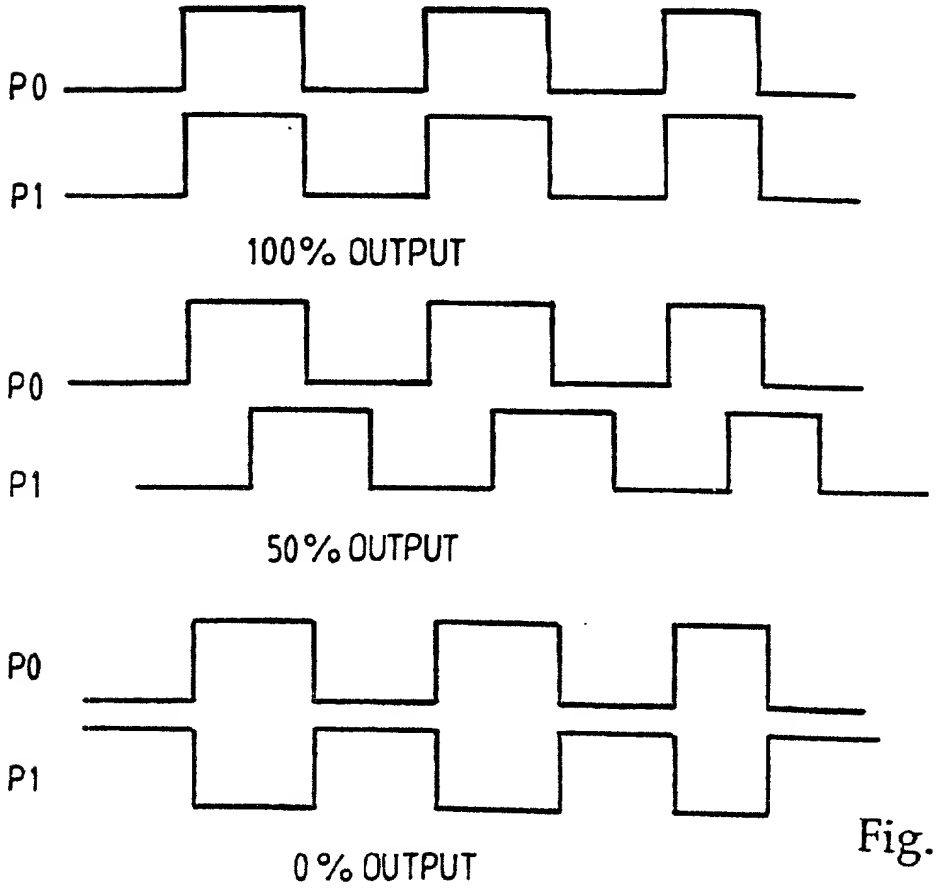
P0
P1
100% OUTPUT
P0
P1
50% OUTPUT
P0
P1
0% OUTPUT

Fig. 2

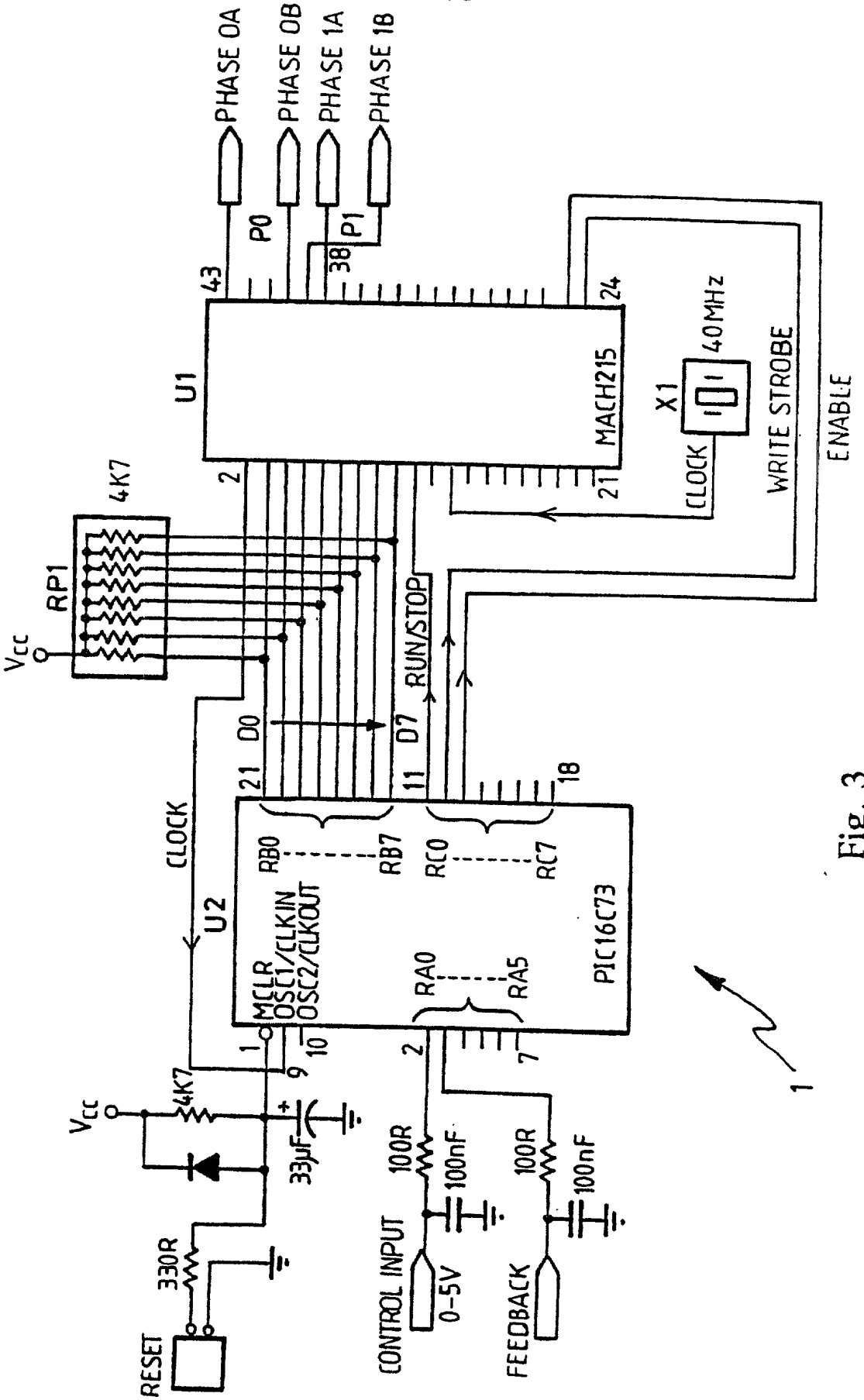
PHASE 0A
PHASE 0B
PHASE 1A
PHASE 1B
P0
P1
43
38
U1
MACH215
24
21
X1
40MHz
CLOCK
WRITE STROBE
ENABLE
2
4K7
RP1
Vcc
D0
D7
RUN/STOP
21
11
18
CLOCK
U2
RB0
RB7
RC0
RC7
MCLR
OSC1/CLKIN
OSC2/CLKOUT
RA0
RA5
PIC16C73
1
10
9
2
7
4K7
Vcc
33µF
100R
100nF
100R
100nF
330R
CONTROL INPUT
0-5V
FEEDBACK
RESET
1

Fig. 3

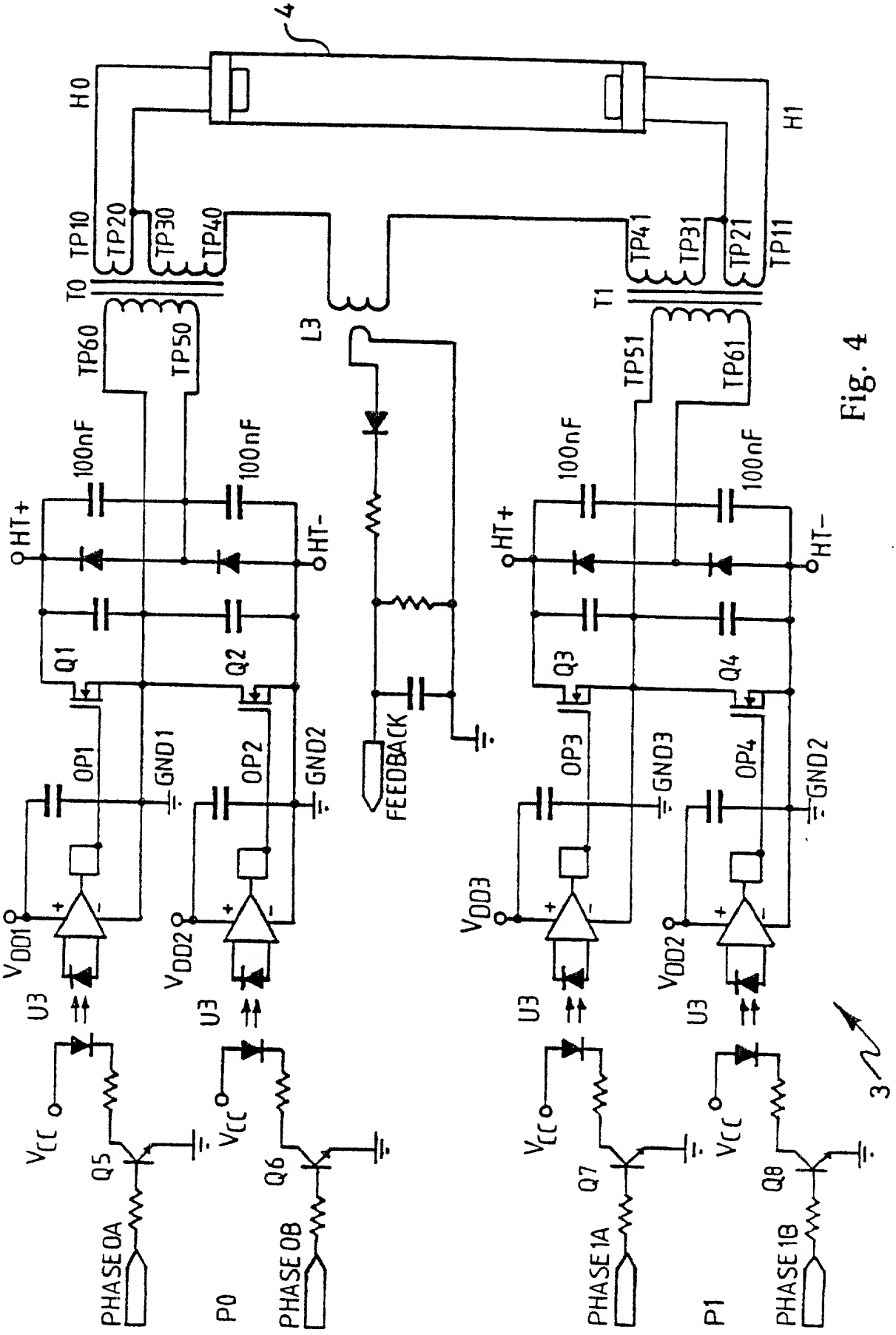
4
H0
H1
TP10
TP20
TP30
TP40
TP41
TP31
TP21
TP11
T0
T1
L3
TP60
TP50
TP51
TP61
100nF
HT+
HT-
Q1
Q2
Q3
Q4
OP1
OP2
OP3
OP4
GND1
GND2
GND3
FEEDBACK
VDD1
VDD2
VDD3
U3
Vcc
Q5
Q6
Q7
Q8
PHASE0A
PHASE0B
PHASE1A
PHASE1B
P0
P1
3

Fig. 4

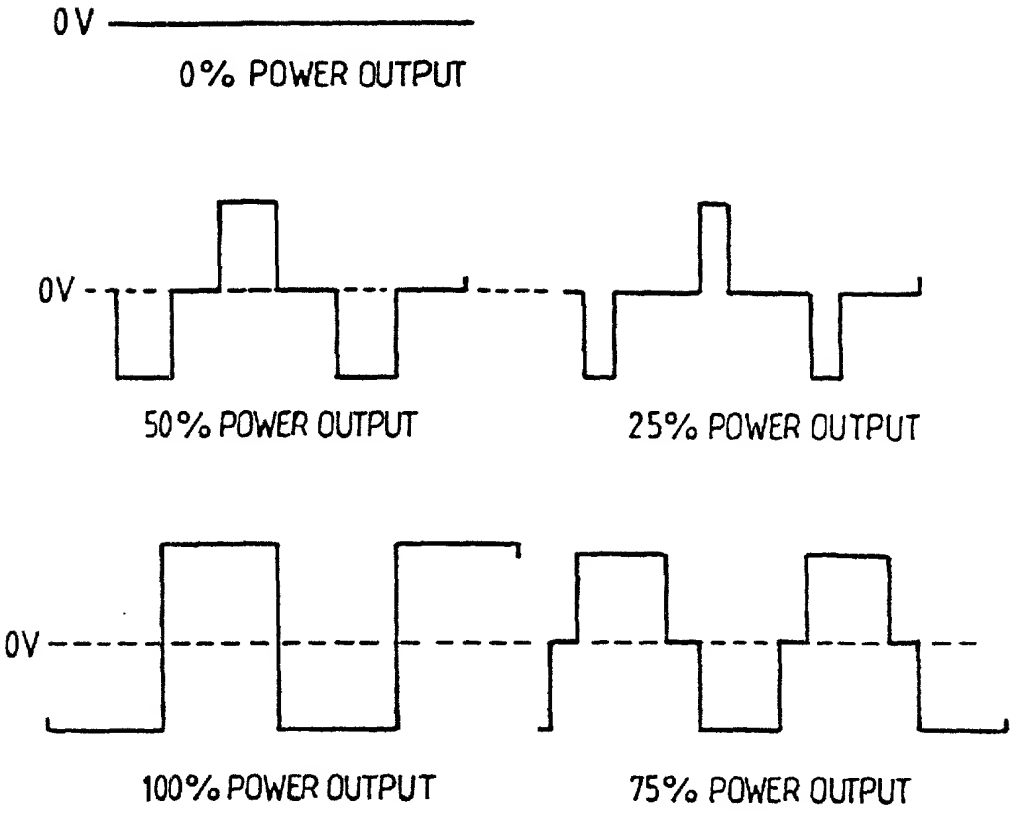

Fig. 5

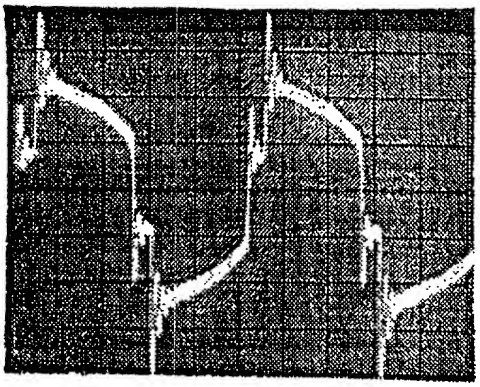

Fig. 6A Step No 219

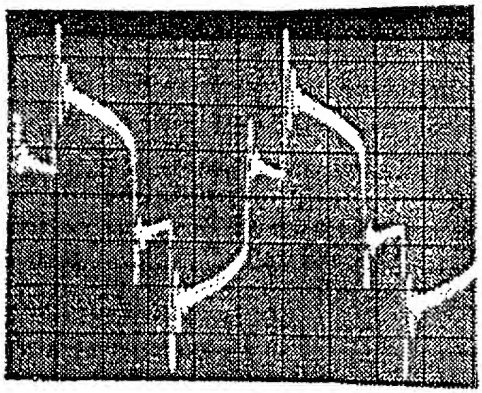

Fig. 6B Step No 173

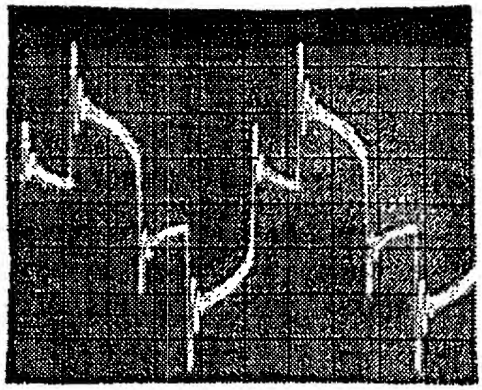

Fig. 6C Step No 150

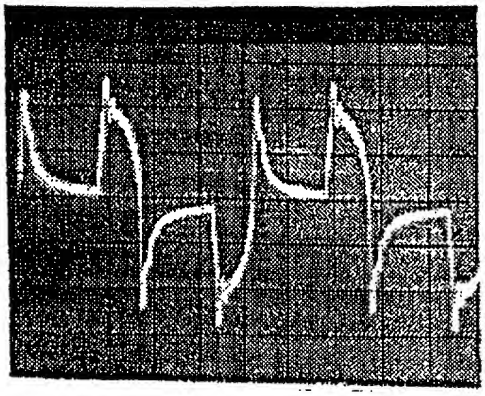

Fig. 6D Step No 120

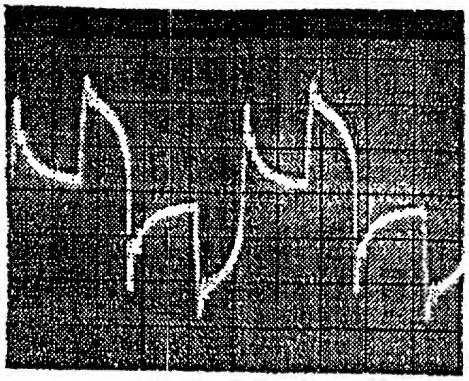

Fig. 6E Step No 106

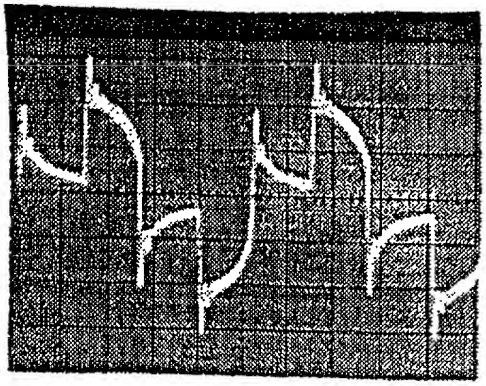

Fig. 6F Step No 90

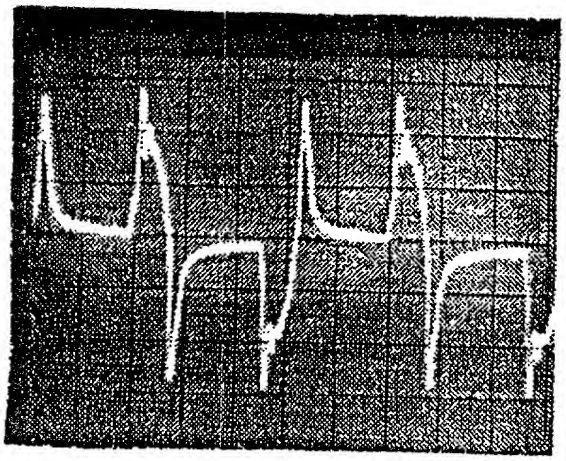

Fig. 6G Step No 77

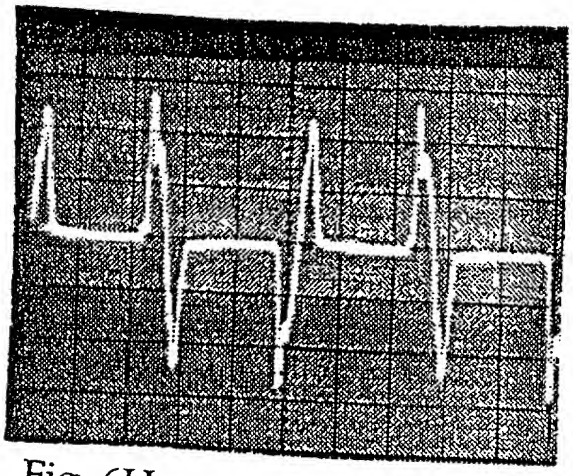

Fig. 6H Step No 62

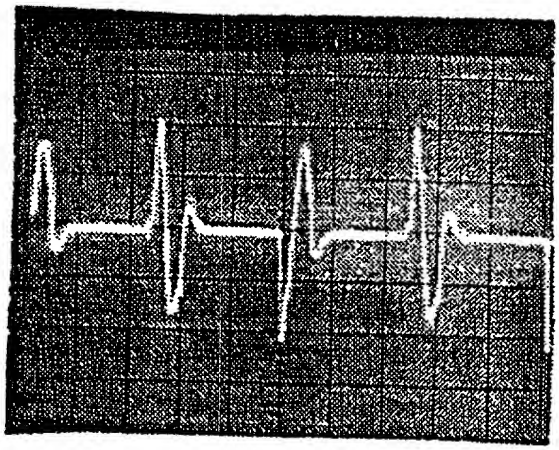

Fig. 6I Step No 50

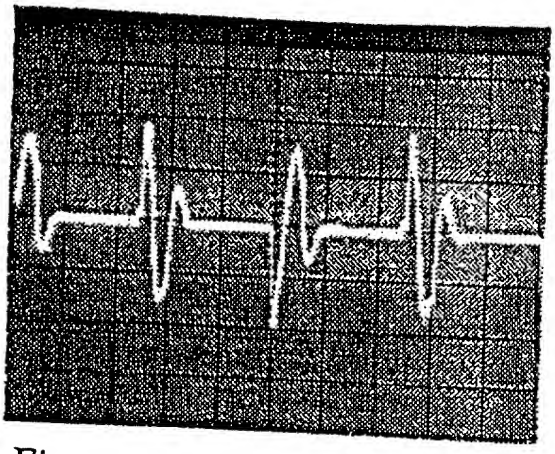

Fig. 6J Step No 47

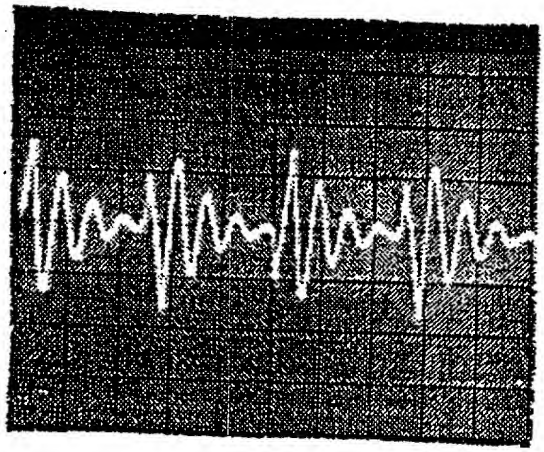

Fig. 6K Step No 28

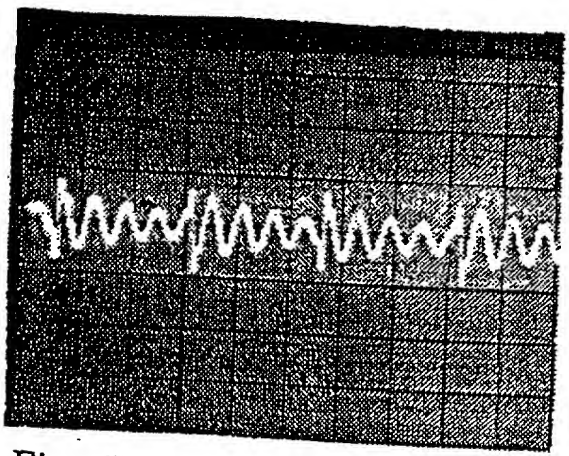

Fig. 6L Step No 1

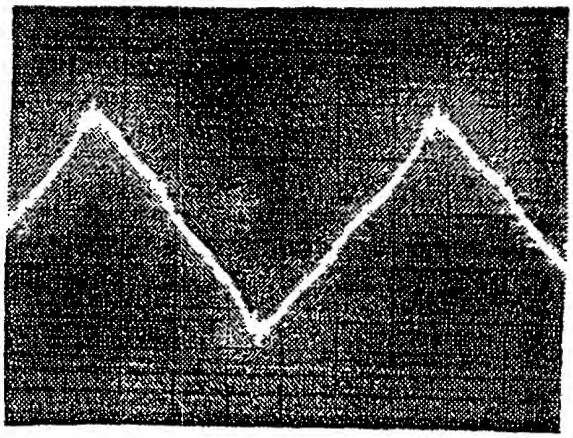

Fig. 7A Step No. 150

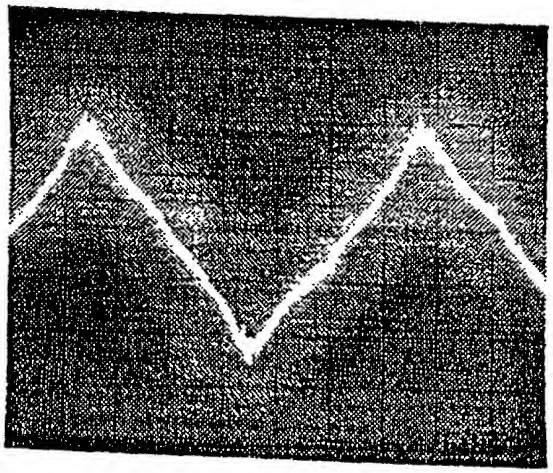

Fig. 7B Step No 120

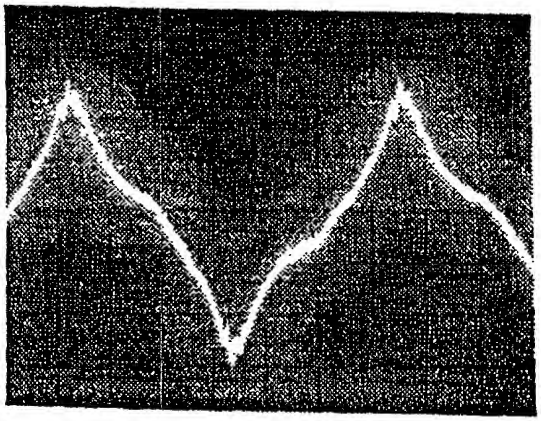

Fig. 7C Step No 106

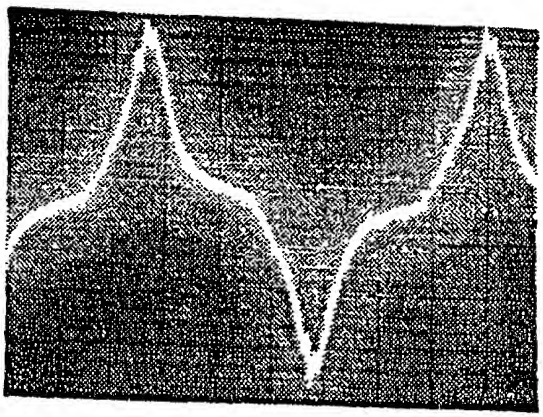

Fig. 7D Step No 90

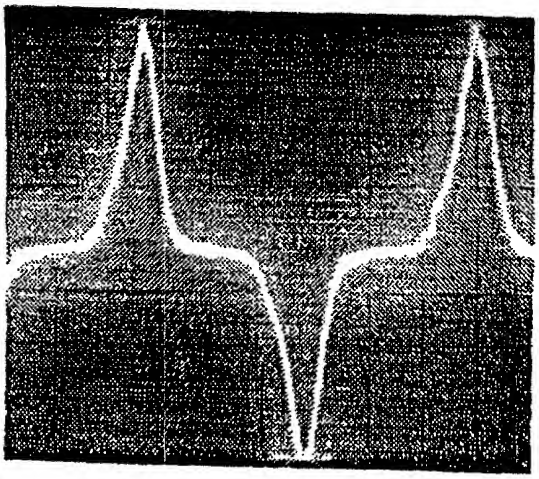

Fig. 7E Step No 77

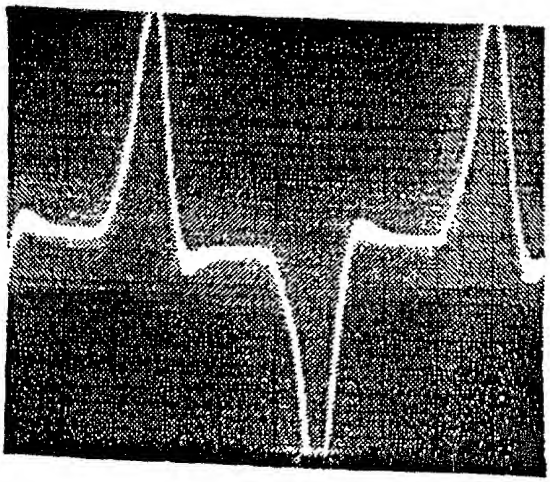

Fig. 7F Step No 62

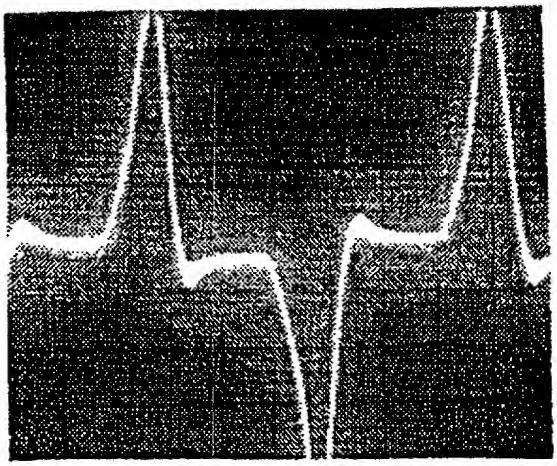

Fig. 7G Step No 50

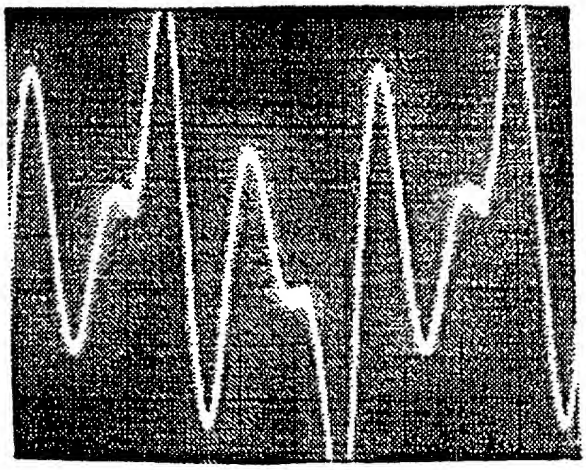

Fig. 7H Step No 28

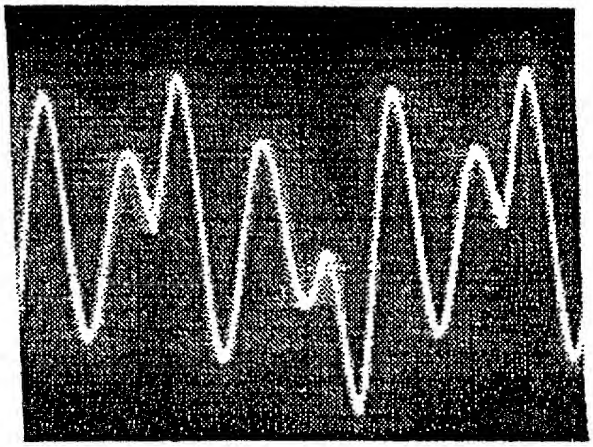

Fig. 7I Step No 1

Practitioner's Docket No. P9153 PATENT

COMBINED DECLARATION AND POWER OF ATTORNEY

(ORIGINAL, DESIGN, NATIONAL STAGE OF PCT, SUPPLEMENTAL, DIVISIONAL, CONTINUATION, OR C-I-P)

As a below named inventor, I hereby declare that:

TYPE OF DECLARATION

This declaration is of the following type:

(check one applicable item below)

- ☒ original.
- ☐ design.
- ☐ supplemental.

NOTE: If the declaration is for an international Application being filed as a divisional, continuation or continuation-in-part application, do not check next item; check appropriate one of last three items.

- ☒ national stage of PCT.

NOTE: If one of the following 3 items apply, then complete and also attach ADDED PAGES FOR DIVISIONAL, CONTINUATION OR C-I-P.

NOTE: See 37 C.F.R. § 1.63(d) (continued prosecution application) for use of a prior nonprovisional application declaration in the continuation or divisional application being filed on behalf of the same or fewer of the inventors named in the prior application.

- ☐ divisional.
- ☐ continuation.

NOTE: Where an application discloses and claims subject matter not disclosed in the prior application, or a continuation or divisional application names an inventor not named in the prior application, a continuation-in-part application must be filed under 37 C.F.R. § 1.53(b) (application filing requirements — nonprovisional application).

- ☐ continuation-in-part (C-I-P).

INVENTORSHIP IDENTIFICATION

WARNING: If the inventors are each not the inventors of all the claims, an explanation of the facts, including the ownership of all the claims at the time the last claimed invention was made, should be submitted.

My residence, post office address and citizenship are as stated below, next to my name. I believe that I am the original, first and sole inventor *(if only one name is listed below)* or an original, first and joint inventor *(if plural names are listed below)* of the subject matter that is claimed, and for which a patent is sought on the invention entitled:

TITLE OF INVENTION

GAS DISCHARGE LAMP DRIVE CIRCUITRY

SPECIFICATION IDENTIFICATION

the specification of which:

(complete (a), (b), or (c))

(a) ☐ is attached hereto.

NOTE: *"The following combinations of information supplied in an oath or declaration filed on the application filing date with a specification are acceptable as minimums for identifying a specification and compliance with any one of the items below will be accepted as complying with the identification requirement of 37 CFR 1.63:*

"(1) name of inventor(s), and reference to an attached specification which is then attached to the oath or declaration at the time of execution and submitted with the oath or declaration on filing;

"(2) name of inventor(s), and attorney docket number which was on the specification as filed; or

"(3) name of inventor(s), and title which was on the specification as filed."

Notice of July 12, 1995 (1177 O.G. 60).

~~(b) ☐ was filed on May 7, 1997, as (if) Serial No. 0~~ GB9709095.7

or ☐ _____

and was amended on _____ *(if applicable).*

NOTE: *Amendments filed after the original papers are deposited with the PTO that contain new matter are not accorded a filing date by being referred to in the declaration. Accordingly, the amendments should be filed with the application papers or, in the case of a supplemental declaration, any added amendments claiming matter not encompassed in the original statement of invention or claims. See 37 CFR 1.67.*

NOTE: *"The following combinations of information supplied in an oath or declaration filed after the filing date are acceptable as minimums for identifying a specification and compliance with any one of the items below will be accepted as complying with the identification requirement of 37 CFR 1.63:*

"(1) name of inventor(s), and application number (consisting of the series code and the serial number; e.g., 08/123,456);

"(2) name of inventor(s), serial number and filing date;

"(3) name of inventor(s) and attorney docket number which was on the specification as filed;

"(4) name of inventor(s), title which was on the specification as filed and filing date;

"(5) name of inventor(s), title which was on the specification as filed and reference to an attached specification which is then attached to the oath or declaration at the time of execution and submitted with the oath or declaration; or

"(6) name of inventor(s), title which was on the specification as filed and accompanied by a cover letter accurately identifying the application for which it was intended by either the application number (consisting of the series code and the serial number; e.g., 08/123,456), or serial number and filing date. Absent any statement(s) to the contrary, it will be presumed that the application filed in the PTO is the application which the inventor(s) executed by signing the oath or declaration."

Notice of July 12, 1995 (1177 O.G. 60), M.P.E.P. § 601.01(a), 6th ed., rev. 3.

(c) ☒ was described and claimed in PCT International Application No. PCT/GB98/01152 filed on May 7 1998 and as amended under PCT Article 19 on _____ *(if any).*

SUPPLEMENTAL DECLARATION (37 C.F.R. § 1.67(b))

(complete the following where a supplemental declaration is being submitted)

☒ I hereby declare that the subject matter of the

☒ attached amendment

☐ amendment filed on _____

was part of my/our invention and was invented before the filing date of the original application, above-identified, for such invention.

ACKNOWLEDGEMENT OF REVIEW OF PAPERS AND DUTY OF CANDOR

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information, which is material to patentability as defined in 37, Code of Federal Regulations, § 1.56,

(also check the following items, if desired)

☒ and which is material to the examination of this application, namely, information where there is a substantial likelihood that a reasonable Examiner would consider it important in deciding whether to allow the application to issue as a patent, and

☐ In compliance with this duty, there is attached an information disclosure statement, in accordance with 37 CFR 1.98.

PRIORITY CLAIM (35 U.S.C. §§ 119(a)-(d))

NOTE: "The claim to priority need be in no special form and may be made by the attorney or agent if the foreign application is referred to in the oath or declaration as required by § 1.63. The claim for priority and the certified copy of the foreign application specified in 35 U.S.C. 119(b) must be filed in the case of an interference (§ 1.630), when necessary to overcome the date of a reference relied upon by the examiner, when specifically required by the examiner, and in all other situations, before the patent is granted. If the claim for priority or the certified copy of the foreign application is filed after the date the issue fee is paid, it must be accompanied by a petition requesting entry and by the fee set forth in § 1.17(i). If the certified copy is not in the English language, a translation need not be filed except in the case of interference, or when necessary to overcome the date of a reference relied upon by the examiner, or when specifically required by the examiner, in which event an English language translation must be filed together with a statement that the translation of the certified copy is accurate." 37 C.F.R. § 1.55(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §§ 119(a)-(d) of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed.

(complete (d) or (e))

(d) ☐ no such applications have been filed.

(e) ☒ such applications have been filed as follows.

NOTE: Where item (e) is entered above and the International Application which designated the U.S. itself claimed priority check item (e), enter the details below and make the priority claim.

PRIOR FOREIGN/PCT APPLICATION(S) FILED WITHIN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS APPLICATION AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. § 119(a)-(d)

COUNTRY (OR INDICATE IF PCT)	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 37 USC 119
PCT	PCT/GB98/01155	May 7/98	☒ YES NO ☐
			☐ YES NO ☐
			☐ YES NO ☐
			☐ YES NO ☐
			☐ YES NO ☐

CLAIM FOR BENEFIT OF PRIOR U.S. PROVISIONAL APPLICATION(S) (35 U.S.C. § 119(e))

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

PROVISIONAL APPLICATION NUMBER	FILING DATE
______ /______________________	______________
______ /______________________	______________
______ /______________________	______________

CLAIM FOR BENEFIT OF EARLIER US/PCT APPLICATION(S) UNDER 35 U.S.C. 120

☐ The claim for the benefit of any such applications are set forth in the attached *ADDED PAGES TO COMBINED DECLARATION AND POWER OF ATTORNEY FOR DIVISIONAL, CONTINUATION OR CONTINUATION-IN PART (C-I-P) APPLICATION.*

ALL FOREIGN APPLICATION(S), *IF ANY*, FILED MORE THAN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS U.S. APPLICATION

NOTE: If the application filed more than 12 months from the filing date of this application is a PCT filing forming the basis for this application entering the United States as (1) the national stage, or (2) a continuation, divisional, or continuation-in-part, then also complete ADDED PAGES TO COMBINED DECLARATION AND POWER OF ATTORNEY FOR DIVISIONAL, CONTINUATION OR C-I-P APPLICATION for benefit of the prior U.S. or PCT application(s) under 35 U.S.C. § 120.

POWER OF ATTORNEY

I hereby appoint the following practitioner(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

(list name and registration number)

TODD N. HATHAWAY, Reg. No. 32,991

(check the following item, if applicable)

☐ I hereby appoint the practitioner(s) associated with the Customer Number provided below to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

☐ Attached, as part of this declaration and power of attorney, is the authorization of the above-named practitioner(s) to accept and follow instructions from my representative(s).

SEND CORRESPONDENCE TO

☑ Address
TODD N. HATHAWAY
119 N. Commercial St. #620
Bellingham, WA 98226-4437

☐ Customer Number _____

DIRECT TELEPHONE CALLS TO:
(Name and telephone number)

TODD N. HATHAWAY
360-647-1976

DECLARATION

I hereby declare that all statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true; and further that th statements were made with the knowledge that willful false statements and the like so m are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the Un States Code, and that such willful false statements may jeopardize the validity of application or any patent issued thereon.

SIGNATURE(S)

NOTE: Carefully indicate the family (or last) name, as it should appear on the filing receipt and all o documents.

NOTE: Each inventor must be identified by full name, including the family name, and at least one given n without abbreviation together with any other given name or initial, and by his/her residence, post o address and country of citizenship. 37 CFR § 1.63(a)(3).

NOTE: Inventors may execute separate declarations/oaths provided each declaration/oath sets forth al inventors. Section 1.63(a)(3) requires that a declaration/oath, inter alia, identify each inventor prohibits the execution of separate declarations/oaths which each sets forth only the name of executing inventor. 62 Fed. Reg. 53,131, 53,142, October 10, 1997.

Full name of sole or first inventor

DAVID (GIVEN NAME) JOHN (MIDDLE INITIAL OR NAME) AARONS (FAMILY (OR LAST NAME))

Inventor's signature ____

Date 25-03-00 Country of Citizenship United Kingdom

Residence Manor Farm, Home Farm Road

Post Office Address Ellingham, Bungay, Suffolk, NR35 2EL

1w

Full name of second joint inventor, if any

JOHN (GIVEN NAME) (nmi) (MIDDLE INITIAL OR NAME) MULLENGER (FAMILY (OR LAST NAME))

Inventor's signature ____

Date ____ Country of Citizenship United Kingdom

Residence Green Farm, Wickham Skeith

Post Office Address Suffolk, IP23 8LX

2w

Full name of third joint inventor, if any

____ (GIVEN NAME) ____ (MIDDLE INITIAL OR NAME) ____ (FAMILY (OR LAST NAME))

Inventor's signature ____

Date ____ Country of Citizenship ____

Residence ____

Post Office Address ____

(check proper box(es) for any of the following added page(s) that form a part of this declaration)

☐ **Signature** for fourth and subsequent joint inventors. *Number of pages added* _____

• • •

☐ **Signature** by administrator(trix), executor(trix) or legal representative for deceased or incapacitated inventor. *Number of pages added* _____

• • •

☐ **Signature** for inventor who refuses to sign or cannot be reached by person authorized under 37 CFR 1.47. *Number of pages added* _____

• • •

☐ **Added page for signature** by one joint inventor on behalf of deceased inventor(s) where legal representative cannot be appointed in time. (37 CFR 1.47)

• • •

☐ **Added pages to combined declaration and power of attorney** for divisional, continuation, or continuation-in-part (C-I-P) application.

☐ Number of pages added _____

• • •

☐ **Authorization of practitioner(s)** to accept and follow instructions from representative.

• • •

(if no further pages form a part of this Declaration, then end this Declaration with this page and check the following item)

☐ This declaration ends with this page.

Practitioner's Docket No. P9153

ADDED PAGE TO COMBINED DECLARATION AND POWER OF ATTORNEY FOR SIGNATURE BY JOINT INVENTOR(S) ON BEHALF OF NONSIGNING INVENTOR(S) WHO REFUSE(S) TO SIGN OR CANNOT BE REACHED (37 CFR 1.47(a))

WARNING: "37 CFR § 1.47(a) and 35 U.S.C. § 116 ¶ 2 require all available joint inventors to file an application 'on behalf' of themselves and on behalf of a joint inventor who 'cannot' be found or reached after diligent effort" or who refuses to 'join in an application.'" M.P.E.P. § 409.03(a), 6th ed., rev. 3 (emphasis added). See also 62 Fed. Reg. 53,131, 53,137, 203 O.G. 68 (Oct. 10, 1997)

I. I am an above named joint inventor and have signed this declaration on my own behalf and also sign this declaration under 37 CFR 1.47(a) on behalf of the nonsigning joint inventor, particulars for whom are:

Full name of (first, second, etc.) John Mullenger nonsigning inventor who

☒ refuses to sign

☐ cannot be found or reached

NOTE: The name of the nonsigning inventor(s) should preferably also be filled in at the appropriate prior space in the declaration, stating the words "nonsigning inventor completed on added page."

Great Britain

Country of Citizenship of nonsigning inventor

Green Farm, Wickham Skeith, Suffolk, IP23 8LX

Last known address of nonsigning inventor

NOTE: Ordinarily, the last known address will be the last known residence of the nonsigning inventor(s). A post office box is insufficient. Other addresses at which the nonsigning inventor(s) may be reached should also be given. These can best be given in the Statement Of Facts In Support Of Filing On Behalf Of Nonsigned Inventor. MPEP § 409.03(d), 6th ed.

II. Accompanying this declaration is:

(1) A STATEMENT OF FACTS IN SUPPORT OF FILING ON BEHALF OF NONSIGNING INVENTOR

(2) THE PETITION FEE OF $130.00 (37 CFR 1.17(i))

David John Aarons

(type or print name of joint inventor signing on behalf of nonsigning inventor)

Signature

Added Page to Combined Declaration and Power of Attorney For Signature By One Joint Inventor On Behalf of Nonsigning Inventor(s) Who Refuse(s) to Sign or Cannot Be Reached [1.47(a)]